CLAIMS

What is claimed is:

1. A method of fractionating charged macro-molecules comprising:

loading molecules into a matrix of obstacles; and

applying an electric field, which varies asymmetrically, to the matrix.

2. The method of claim 1 wherein the step of applying an asymmetric electric field to the matrix comprises applying an electric field which is alternating in direction as a function of time at a location in the matrix, and which has a time average of its vector over many cycles, whereby the time integral of the electric field vector at the same location over the part of the cycles when it is instantaneously pointing to one side of the said time-averaged electric field vector is not spatially symmetric about the same said time-averaged vector with the time integral of the electric field vector over the part of the cycles at the same location when it is instantaneously pointing to the other side of the same said time-averaged vector.

3. The method of claim 1 wherein the step of applying an asymmetric electric field to the matrix comprises applying to the matrix time-dependent electric fields $\vec{E}(t)$ whose odd-order integrals over time, $\int |\vec{E}(t)|^n \vec{E}(t)dt$, are not at the time-average field orientation for every n, where n is any positive even integer.

4. The method of claim 1 wherein the electric fields comprise:

alternating first and second electric pulses of first and second waveforms;

maintaining the integral of one of the first or second pulses' amplitude over time larger than that of the other pulse;

varying the orientation of the first electric pulse within first orientation and second orientation, and the orientation of the second electric pulse within third orientation and forth orientation.

5. The method of claim 4 wherein the first and second waveforms are square pulses.

6. The method of claim 5 wherein one of the square pulses is of higher amplitude than the other.

7. The method of Claim 5 wherein one of the square pulses is of longer duration than the other.

8. The method of Claim 1 wherein the electric fields comprise:

alternating first and second electric pulses of first and second waveforms;

maintaining the integral over time of one of the first or second pulses' amplitudes larger than that of the other pulse;

applying the first and second electric pulses at first and second fixed orientations.

9. The method of claim 8 wherein the first and second waveforms are square pulses.

10. The method of claim 9 wherein one of the square pulses is of higher amplitude than the other.

11. The method of claim 9 wherein one of the square pulses is of longer duration than the other.

12. The method of claim 1 wherein the charged macro-molecules are deoxyribonucleic acid (a.k.a. DNA).

13. The method of claim 1 wherein the process is operated continuously.

14. The method of claim 1 wherein the molecules are extracted from the array of obstacles.

15. The method of claim 1 wherein the molecules are loaded using electric fields.

16. The method of claim 1 wherein the molecules are extracted from the array of obstacles using electric fields.

17. The method of claim 1 wherein the molecules are routed to the next processing step after fractionation.

18. A method of fractionating charged macro-molecules comprising:

loading molecules into a matrix with an array of obstacles;

applying to the matrix electric fields whose amplitudes are constant in time;

varying the field orientation with time to create an asymmetrical electric field.

19. The method of claim 18 wherein the step of varying the field orientation with time to create an asymmetrical electric field comprises varying the field orientation with time in such a manner that $\int[\theta(t)]^{n+1}dt$ are not zero for every n, where $\theta(t)$ is field orientation with respect to the time-average field orientation, and n is any even integer larger than zero.

20. The method of claim 19 wherein the fields alternate between two fixed orientations.

21. The method of claim 18 wherein the charged macro-molecules are deoxyribonucleic acid (a.k.a. DNA).

22. The method of claim 18 wherein the process is operated continuously.

23. The method of claim 18 wherein the molecules are extracted from the array of obstacles.

24. The method of claim 18 wherein the molecules are loaded using electric fields.

25. The method of claim 18 wherein the molecules are extracted from the array of obstacles using electric fields.

26. The method of claim 18 wherein the molecules are routed to the next processing step after fractionation.

27. An apparatus for fractionating charged macro-molecules comprising an array of obstacles and asymmetrically alternating electric fields.

28. The apparatus of claim 27 wherein the asymmetrically alternating electric fields comprise:

an electric field which is alternating in direction as a function of time at a location in the matrix, and which has a time average of its vector over many cycles, whereby the time integral of the electric field vector at the same location over the part of the cycles when it

is instantaneously pointing to one side of the said time-averaged electric field vector is not spatially symmetric about the same said time-averaged vector with the time integral of the electric field vector over the part of the cycles at the same location when it is instantaneously pointing to the other side of the same said time-averaged vector.

29. The apparatus of claim 27 wherein the asymmetrically alternating electric fields comprise:

time-dependent electric fields $\vec{E}(t)$ whose odd-order integrals over time, $\int|\vec{E}(t)|^n \vec{E}(t)dt$, are not at the time-average field orientation for every n, where n is any positive even integer.

30. The apparatus of claim 27 wherein the asymmetrically alternating electric fields comprise:

first and second electric pulses of first and second waveforms;

the integral over time of one of the first or second pulses' amplitude larger than that of the other pulse;

the orientation of the first electric pulse varying between a first orientation and second orientation, and the orientation of the second electric pulse varying between a third orientation and forth orientation.

31. The apparatus of claim 30 wherein the first and second waveforms are square pulses.

32. The apparatus of claim 31 wherein one of the square pulses is of higher amplitude than the other.

33. The apparatus of claim 31 wherein one of the square pulses is of longer duration than the other.

34. The apparatus of claim 27 wherein the asymmetrically alternating electric fields comprise:

first and second alternating electric pulses of first and second waveforms;

the integral over time of one of the first or second pulses' amplitudes larger than that of the other pulse;

the first and second electric pulses applied at first and second fixed orientations.

35. The apparatus of claim 34 wherein the first and second waveforms are square pulses.

36. The apparatus of claim 35 wherein one of the square pulses is of higher amplitude than the other.

37. The apparatus of claim 35 wherein one of the square pulses is of longer duration than the other.

38. The apparatus of claim 27 wherein the asymmetrically alternating electric fields comprise:

electric fields whose amplitudes are constant in time;

the field orientation varying with time in such a manner that $\int[\theta(t)]^{n+1}dt$ are not zero for every n, where $\theta(t)$ is field orientation with respect to the time-average field orientation, and n is any even integer larger than zero.

39. The apparatus of claim 38 wherein the fields alternate between two fixed orientations.

40. The apparatus of claim 27 wherein the charged molecules are deoxyribonucleic acid (a.k.a. DNA).

41. The apparatus of claim 27 wherein the apparatus is operated continuously.

42. The apparatus of claim 27 wherein the apparatus comprises extraction structures for extracting fractionated molecules from the array of obstacles.

43. The apparatus of claim 27 wherein the apparatus comprises loading channel(s) for loading molecules.

44. The apparatus of claim 27 wherein the molecules are extracted from the array of obstacles using electric fields.

45. The apparatus of claim 27 wherein the molecules are loaded into the array of obstacles using electric fields.

46. The apparatus of claim 27 wherein the molecules are routed to the next processing step after fractionation.